Parkins (1979) presented similar data on the effects of straining and aging, and he was able to show a strong correlation between the effects on creep resistance and the effects on threshold stress. That correlation also has been confirmed in a study of three X52 steels by Christman (1988b).

Susceptibility to Near-Neutral pH SCC. In a detailed study of 14 joints of pipe (from four pipeline companies) that contained patches of near-neutral pH stress corrosion cracks, no significant differences between the cracked areas and uncracked areas were found in terms of composition, microstructure, and inclusion size, inclusion shape, or inclusion composition. The SCC areas might have been about 3 percent harder on average (Beavers, Johnson, and Sutherby 2000). However, the most significant finding of this study was that the occurrence of SCC was highly correlated with residual stresses in the pipe.

A laboratory study of two X65 steels and an X80 steel indicated no measurable difference in crack growth rates among the three steels, as measured on compact-tension specimens in NS4 solution sparged with 10 percent CO_2/N_2 gas (Meyer and Pontremoli 2001).

A claim has been made that steels with a "more uniform" microstructure (e.g., bainite or bainite plus ferrite) are more resistant to near-neutral pH SCC than are steels with a non-uniform (ferrite plus pearlite) microstructure, (Kushida et al. 2001) but the test conditions involving negative potentials (generally around –930 mV SCE or –1.0 volt $Cu/CuSO_4$) and low stress ratios (R values of 0.5 and 0.7) suggest that the fracture mechanism may have been hydrogen-assisted corrosion fatigue rather

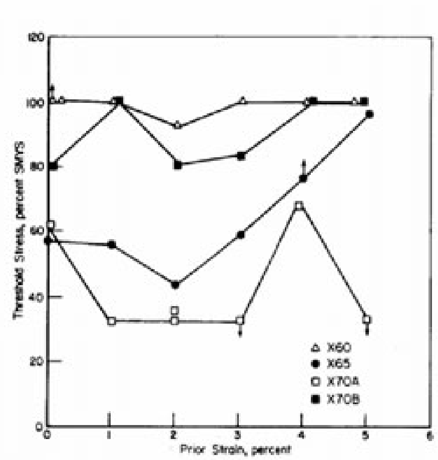

Figure A-13-22 Effect of Prior Strain on Threshold Stress for High pH SCC of Various Line-Pipe Steels

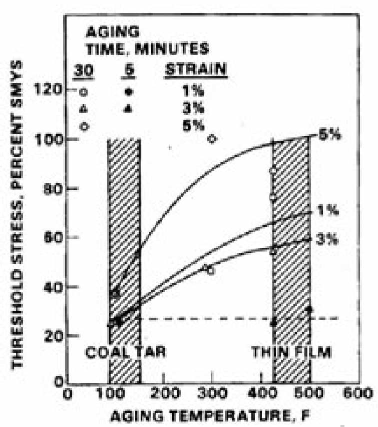

Figure A-13-23 Effects of Thermal Treatments on the Susceptibility of Cold-Worked X65 Steel to High pH SCC

than SCC. However, another study found similar results for more realistic testing conditions (Meyer et al. 2003).

Whereas the bulk microstructure appears to have little effect on SCC susceptibility, the same is not necessarily true for weld heat-affected zones. In one study, the crack growth rate in a coarse-grained weld heat-affected zone was found to be about 4 times higher than in the base metal (Beavers, Durr, and Shademan 1998).

Possible Research Approaches. The key to developing more resistant steels seems to be to increase the resistance to cyclic creep. However, that hypothesis is based on limited direct evidence and some scattered indirect evidence, almost entirely for high pH SCC. More experiments to directly test the hypothesis for both high pH and near-neutral pH SCC probably would be justified before embarking on a long effort to relate the cyclic-creep resistance under a variety of stressing conditions to the composition, processing, microstructure, and thermomechanical history. The latter effort probably would require a substantial amount of basic research followed by another significant effort in making and testing experimental steels.

An alternative approach, which is currently being used by researchers in Europe and Japan, is to prepare a number of steels with a variety of microstructures and properties by varying the composition and thermo-mechanical treatment, and then developing empirical correlations between measured susceptibility to SCC and the composition, mechanical properties, and microstructure.

In view of the recent evidence pointing to residual stresses as possible contributing factors to determining where SCC occurs in the field, research into ways to minimize such stresses through modifications of the manufacturing process might be beneficial.

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Attachment A
Operator Questionnaire

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Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation

Airside Business Park
100 Airside Drive
Moon Township, PA 15108
(412) 269-6023
(412) 375-3996 (FAX)

February 13, 2004

Dear Pipeline Operator:

Michael Baker Jr., Inc., a full service engineering firm providing engineering and energy expertise for public and private clients worldwide, has been contracted by the U.S. Department of Transportation Research and Special Programs Administration's Office of Pipeline Safety (OPS) to provide expert technical assistance to them under their Integrity Management Initiative. Since 2002, Baker has supported OPS through technical studies and assessments on issues ranging from ecological effects of releases from HVL pipelines, evaluation of longitudinal seams of LF-ERW pipe and lap welded pipe, and an evaluation of wrinkle bends and buckles in pipelines.

In this current effort, Baker is assisting OPS with a study of Stress Corrosion Cracking (SCC) issues relating to pipeline integrity for both gas and liquid lines, including history of SCC, level of risk, indicators of potential for SCC, detection methods, mitigation measures, and assessment procedure. An initial step in the study process was the workshop on SCC held on December 2, 2003, in Houston, Texas, where Baker presented an outline of the study effort. OPS and the National Association of Pipeline Safety Representatives (NAPSR) cosponsored this workshop along with API, AOPL, INGAA, AGA and NACE.

Baker has prepared the attached survey document to assist in gathering information from pipeline operators on SCC occurrence history and operating company practices for SCC detection, management and mitigation. We are asking for your cooperation in supplying this information so that we can have as complete a picture as possible on the practices currently being employed to address SCC. It is our intent to selectively follow-up with more in-depth interviews with some operators to learn more about the effectiveness of measures taken by operators for dealing with SCC. OPS intends that the study be made public, which will be later in 2004.

Baker wishes to thank the industry trade organizations for their support of this study effort. The survey itself has been reviewed by a working group led by Dave Johnson of Enron and its final format has been developed with the cooperation of that group.

We are requesting that the survey be returned to Baker by March 3, 2004. It can be returned electronically to me at cmayernik@mbakercorp.com, mailed to me at the above address, or faxed to me at 412-375-3996

We appreciate your efforts in completing this survey. If you have any questions, please contact me at 412-269-6023.

Sincerely,

Christine S. Mayernik, P.E.
Project Manager

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PIPELINE OPERATOR RESPONSE

STRESS CORROSION CRACKING STUDY

Conducted by Michael Baker, Jr., Inc.
In support of

US DOT RSPA/Office of Pipeline Safety
Contract No. DTRS56-02-D-70036
Technical Task Order 8 – SCC Study

Baker has been tasked by OPS to conduct a study of Stress Corrosion Cracking (SCC). The study effort will include discussion of the current state of knowledge by operators regarding SCC. Through this survey instrument and follow-up select interviews, the study will attempt to address the following questions:

- *Are operators are being prudent in the detection, management and mitigation of SCC?*
- *How are operators addressing SCC in their Integrity Management Programs?*
- *How effective are measures taken by operators to mitigate SCC?*
- *What are best industry practices with regard to SCC?*
- *What gaps exist in operator knowledge, application and response that need to be addressed to improve SCC detection, management and mitigation?*

Baker appreciates the support of INGAA, AOPL and API in their assistance and endorsement of this survey effort and of their support of the study.

Operator Information

Company Name:

Address:

Contact Name:

Contact Title:

Phone Number

Fax Number:

Email Address:

SCC Occurrence Information

1. Has SCC been detected on any of your pipelines in the past? ☐ Yes ☐ No
   a. If YES, when was SCC first detected on your pipeline system? ____________
   b. If YES, what was the system age at that time? ____________
2. Approximate number of SCC in-service failures: ____________
3. Approximate number of hydrostatic test failures: ____________
4. How prevalent is SCC on your system?
   a. Number of main line valve sections where SCC has been detected: ____________
   b. Percentage of total number of valve sections: ______%
5. If SCC occurrence was found during an inspection(s), what was the reason for the inspection(s)?

   ☐ Looking for SCC ☐ Other (please describe:)

6. Product in pipeline where SCC was found:

   ☐ Natural Gas ☐ Liquid ☐ Other: ____________

7. Has an in-service failure or a hydrostatic test failure at or below the prior test pressure occurred on a line segment previously subjected to SCC mitigation activities?

   ☐ Yes ☐ No

   a. If YES, how many years elapsed from initial occurrence or discovery to the failure?

SCC Occurrence Information (cont.)

8. Geographic region or state/province where SCC has been detected:

Please provide a range of pipeline characteristics where SCC has occurred:

OD:

Wall Thickness:

Grade:

Year Installed:

Coating Type:

Operating Pressure:

Operating Temperature:

Soil Type and Condition:

Other relevant information:

SCC Detection Methods

What NDE methods has your company used to identify SCC?
(check all that apply)

☐ **Visual**

(The pipe is exposed and the pipe coating is examined for soundness and performance. Some coating is removed at locations where disbanding is suspected. A technician examines the pipe after removing the coating. The technician then examines the pipe for evidence of cracks.)

☐ **Magnetic Particle**

(The pipe in question is examined visually with the assistance of magnetic particle imaging.)

☐ **Liquid Dye Penetrant**

(The use of dyes on the surface of the pipe to enhance the visualization of cracks.)

☐ **Eddy Current**

(The use of eddy currents to measure the occurrences of cracking.)

☐ **ILI Tool (type of tool used:** ______________________________)

☐ **Other (please describe:** ______________________________)

Does your company have written procedures that:

- **Describe reassessment intervals if SCC is detected?** ☐ Yes ☐ No
- **Describe physical field practices for SCC detection?** ☐ Yes ☐ No
- **Describe NDE evaluation procedures?** ☐ Yes ☐ No

Other information or comments:

SCC Management

Which of the following practices does your company use to manage SCC?
(check all that apply)

☐ **Failure History Characterization**

(Use information of past SCC failures as an indication of the specific conditions that may result in the future occurrence of SCC.)

☐ **Coating Type Characterization (Coal tar, tape, etc.)**

(Characterizes the condition and type of coating, and correlates the information with the occurrence of SCC.)

☐ **Pipe Material Characterization (API Grades, Pipe Mill, etc.)**

(Characterizes the type of pipe and correlates it to the occurrence of SCC.)

☐ **Operation Characterization (Pressure, Temperature, etc.)**

(Correlates the specific operating conditions of the pipeline with the occurrence of SCC.)

☐ **Location Characterization**

(Correlates the environmental conditions near the pipe with the occurrence of SCC.)

☐ **Age Characterization**

(Correlates the age of the facilities with the occurrence of SCC.)

☐ **Bell Hole Characterization**

(Results of buried pipe inspection reports are utilized to determine if there are common characteristics in pipe with SCC compared to pipe with no SCC utilizing trending analysis..)

☐ **Magnetic Flux Leakage ILI Characterization**

(Utilization of MFL pigs to detect wall loss primarily due to corrosion.)

☐ **Other ILI Characterization**

(Utilization of other pigs to detect SCC.)

☐ **Cathodic Protection Level Characterization (Voltage Levels)**

(Monitoring of CP voltage levels at locations with and without active SCC for use as a predictive tool.)

☐ **Hydrostatic Retest Program**

(Destructively testing pipe to determine presence of SCC.)

☐ **External Corrosion Direct Assessment**

☐ **Risk Assessment Ranking (Segment by Segment Comparison)**

Does your company have written procedures for SCC management? ☐ **Yes** ☐ **No**

If YES, how long have you had written procedures?

SCC Management (cont.)
Describe any SCC predictive models used by your company

SCC Mitigation

What actions does your company use to mitigate SCC (or SCC failures)?

(check all that apply)

- ☐ **Operating Condition Modification (Pressure or temperature reduction, etc.)**
- ☐ **Selective Sleeve Installation**
- ☐ **Clean Pipe and Recoat**
- ☐ **Grind Pipe and Recoat**
- ☐ **Soil Condition Modification (Drainage pattern change, replacement or chemical treatment of soil, etc.)**
- ☐ **Other (please describe below:)**

Does your company have written procedures for SCC mitigation? ☐ **Yes** ☐ **No**

Please return form (preferably in electronic format) by March 1, 2004, and address any questions to:

Christine S. Mayernik, P.E.
Michael Baker Jr., Inc.
Airside Business Park
100 Airside Drive
Moon Township, PA 15108
(412) 269-6023 (direct)

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Attachment B
Operator Interview

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2004/G478

Department of Transportation
Research and Special Programs Administration
Office of Pipeline Safety

Integrity Management Program
Delivery Order DTRS56-02-D-70036

Stress Corrosion Cracking Study

<u>Agenda for Operator Interview</u>

DRAFT

Michael Baker Jr., Inc.
2004

ChallengeUs.

Operator Interview Regarding SCC Procedures

General Guidelines

Instructions for Interviewer:

What follows is a suggested agenda for the Operator Interviews regarding SCC. Although the agenda is formal in nature, the interviewers are encouraged to have informal discussions on any area of interest germane to the general topic that the operator wants to discuss.

The general topics listed have a number of suggested sub-topics suggested. It is well recognized that not all, and perhaps few, of the subtopics are expected to be addressed by any individual operator and they are largely meant as reminders of areas of interest. On the other hand, the subtopics are not meant to be exhaustive and additional information is welcomed.

Operator Written Information:

Written information (reports, forms, publications, records…) of any kind can only be received from the operator with the understanding that the information may be referenced within a public document. Although Baker's report will not reference operators information by name, unless specifically authorized to do so, receipt of written information cannot be guaranteed to be kept confidential.

The report would, however, like to simply list those operator companies (with no personnel contact names) who were interviewed and the interviewer should notify the operator of this intent.

Interview Notes:

The notes from the interview should be recorded in a timely manner and transmitted back to the operator for editing, clarification, additions by the operator. The operator should be notified that a timely response (within 3 business days) is desired. Report information will be based on these notes, but the notes will not be included in the report.

Suggested Agenda

1. General Background Information
    - General Contact Information
    - Pipeline Characteristics – commodity, miles, diameter, throughput…
    - IM Organization

- IM Contact Information
- SCC Technical Resources

2. SCC Historical Information
    - SCC Discovery
    - SCC Incidents
    - Followup
3. General Approach to SCC
    - Plans
    - Education, Training
    - Tracking Database/records
    - Maintenance Procedures (e.g. SCC awareness during excavations)
    - Participation in Research
    - Ongoing Activities
    - Future Plans
4. SCC Prevention Specifics
    - Considerations for New Construction
        - Linepipe Considerations
        - Coatings
        - Specifications
        - Approved Materials
        - Surface Preparation
        - Corrosion Allowance
        - Design Practices
    - Construction Practices
    - Operations & Maintenance
        - CP
        - Recoating existing lines
        - Monitoring/Controlling cyclic pressure fluctuations
        - Other?
5. SCC Detection

- Predictive models
- Hydrostatic testing
- Field excavations
- ILI
- Other?

6. SCC Assessment
   - Direct assessment
   - Direct examination
   - Analytical techniques
   - Prioritization for mitigation/remediation
7. Mitigation of SCC
   - Pressure reduction
   - Field repair techniques
8. Post-Incident Response
   - Lower operating pressure
   - Lower operating temperature
   - Hydrostatic testing
9. Industry Views
   - Lead Organizations
   - Ongoing studies being followed/participated
   - Suggested studies
   - Regulation and oversight
10. SCC Study Evaluation
    - Critique of interview
    - Ways to improve interview